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SELECTION FOR BROWN SHRIMP, *PENAEUS AZTECUS*, AS PREY BY THE SPOTTED SEATROUT, *CYNOSCION NEBULOSUS*

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ABSTRACT

Prey selection by spotted seatrout (*Cynoscion nebulosus*) (160–210 mm TL) was examined in the laboratory to provide information on predator-prey interactions in estuarine systems. In tanks without an accessible substrate for burrowing, seatrout fed exclusively on brown shrimp (*Penaeus aztecus*) and did not eat juvenile spot (*Leiostomus xanthurus*). In tanks with a sand substrate, some spot were eaten, but selection for brown shrimp was still significant. Burrowing by shrimp into the substrate apparently reduced their availability to the predators. Prey ranged in size from 59 to 85 mm (TL), and seatrout selected shrimp and fish within the lower half of this size range. In a separate feeding trial, spotted seatrout selected juvenile spot over juvenile pinfish (*Lagodon rhomboides*).

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INTRODUCTION

The occurrence of penaeid shrimp in stomach contents of predatory estuarine fishes indicates that predation is a potentially important component of natural mortality of shrimp in estuaries. Many studies have identified the spotted seatrout (*Cynoscion nebulosus*) as a major predator of penaeid shrimp (Pearson 1928, Knapp 1949, Miles 1950, Kemp 1950, Moody 1950, Stewart 1961, Seagle 1969). In contrast, other studies have shown that juvenile fish are abundant in the stomachs of spotted seatrout, and that penaeid shrimp are a relatively minor dietary component although present in samples of available prey (Darnell 1958; Lorio and Shafer 1966; Fontenot and Rogillio 1970; Diener, Inglis and Adams 1974; Danker 1979). This variability in the diet of seatrout makes it difficult to assess the impact of predation by these fish on shrimp populations and emphasizes the need for information on prey selection by spotted seatrout.

Accurate information on prey selection of predatory fishes cannot be obtained through stomach content analyses without information on the availability of prey species. For planktonic systems, O'Brien and Vinyard (1974) discussed the problems involved in sampling available prey, such as gear selectivity and nonrandom prey distributions in the water column. Determining prey availability may be even more difficult in estuarine predator-prey systems, where predators such as spotted seatrout feed both on the bottom and in the water column. Measurements of prey density do not necessarily measure prey availability to predators. In addition to prey density, availability is affected by differences in prey detectability (Zaret 1972, Kislalioglu and Gibson 1976, Zaret 1980) and catchability (Ivlev 1961, McPhail 1969, Stein 1979), and these two factors can interact with environmental characteristics such as substrate type (Ware 1972, Stein and Magnuson 1976) and the presence of vegetation (Savino and Stein 1982, Minello and Zimmerman 1983). To understand spotted seatrout-shrimp interactions, it is important to know whether seatrout select shrimp over other prey, and whether environmental characteristics, such as the type of substrate, affect selection.

In this study we examined prey selection by spotted seatrout in the laboratory. Prey consisted of juvenile brown shrimp (*Penaeus aztecus*), spot (*Leiostomus xanthurus*), and pinfish (*Lagodon rhomboides*). Equal prey densities and sizes were maintained, and the effect of substrate type on the selection process was determined.

METHODS AND MATERIALS

The six spotted seatrout (160–210 mm TL) used in feeding trials were collected by seine in Galveston Bay, Texas, during the fall of 1982 and spring of 1983. For 1 month prior to observations on prey selection, and between feeding trials, the seatrout were fed equal numbers of live brown shrimp and juvenile spot. Seatrout were examined daily and were only fed after all prey from previous feedings were eaten. This feeding regime gave the seatrout experience with both experimental prey. In addition, the feeding regime was essentially maintained through feeding trials, since an equal number of both prey species was present at the start of each feeding trial. Experience gained in one feeding trial, therefore, should not have strongly affected the results of subsequent feeding trials with the same predators. We considered feeding the seatrout an entirely different type of food before feeding trials, but this procedure can introduce a bias in selection for prey most similar to the type of food chosen (Coppinger 1970).

Prey were collected from Galveston Bay and held in the laboratory for a maximum of 1 week before feeding trials. Shrimp were fed pelleted food, and juvenile fish were fed a commercial flaked fish food or small pieces of shrimp. Juvenile spot were chosen as an alternative prey to shrimp because: 1) spot have been reported to commonly occur in spotted seatrout stomachs (Pearson 1928), 2) juvenile spot are abundant in Galveston Bay throughout the spring and summer, and 3) spot are relatively hardy and survive well in the laboratory.

Observations on selection for brown shrimp versus spot were made in a large elliptical concrete tank (13.4 m^2 bottom area) with an undergravel filtering system and a sand substrate. In the first two feeding trials, which were replicates, a 2-mm plastic mesh was placed over the sand to examine prey selection with no accessible substrate for burrowing. The third and fourth feeding trials were also replicates and were conducted without the mesh to examine the effect of substrate accessibility. Light was provided through two skylights, and water temperature and salinity were maintained at 26°C and 21–22‰, respectively.

The tank was divided into four sectors of equal size (3.4 m^2 bottom area) by two walls of 3.2-mm plastic mesh. Two spotted seatrout were placed in a release cage (0.6-m diameter) in each of three sectors and starved for 24 hr. Approximately 20 hr before releasing the predators, 20 brown shrimp and 20 spot were measured and placed in each of the four sectors. The fourth sector was used as a control to examine prey interactions and mortality not due to predation by trout. The release cages were lifted at 1200 hr and the trout were allowed to feed for 24 hr. The tank was then drained and the remaining prey in each sector were counted and measured. In the initial feeding trial (one of the two feeding trials with no accessible substrate for burrowing), one of the dividing walls was inadvertently removed after the predators and prey had been introduced, but before the predators were released. In this feeding trial, two of the seatrout were removed, and the four remaining seatrout occupied one half of the tank with 40 shrimp and 40 spot. The other half of the tank was used as the control. Initial densities of both spot and shrimp in all feeding trials were 5.9/m^2.

Similar size-frequency distributions were selected for each prey species to prevent size selection from confounding our results. The size ranges for spot and shrimp were 60–84 mm TL and 59–85 mm TL, respectively. Size-selective predation on shrimp was examined from prey selection feeding trials. Since few spot were eaten when shrimp were present, size-selective predation on spot was examined in an independent feeding trial, in which spot were the only prey available. Again, the initial prey density in each of the three sectors of the experimental tank was 5.9/m^2 (20/sector). The predators were allowed to feed until approximately one-third of the available prey were consumed.

Between feeding trials the spotted seatrout were held in small containers (0.28 to 0.56 m^2 bottom area) with substrates which prevented shrimp from burrowing. Feeding in these holding containers provided an additional opportunity to examine prey selection. One brown shrimp and one spot, of similar size, were offered simultaneously to the seatrout, and the tanks were monitored to determine the prey species eaten first. After the fish had eaten both prey, the process was repeated.

To determine whether spot were avoided as prey in relation to other juvenile fish, prey selection between spot and juvenile pinfish was also examined. For 6 days before observations on selective predation, the seatrout were fed equal numbers of pinfish and spot. One seatrout was then placed in each of six circular cages (0.28-m^2 bottom area) in the large concrete tank. One spot and one pinfish of similar size (58 to 83 mm TL) were added to each cage, and the cages were monitored to determine the prey species eaten first. After 24 hr all remaining prey were removed, and one individual of each prey species was again added to each cage. This procedure was repeated for 6 days.

RESULTS

In the feeding trials conducted in the large concrete tank without an accessible substrate for burrowing, spotted seatrout fed exclusively on juvenile brown shrimp (Table 1). In the two feeding trials with a sand substrate, some spot were eaten, but the seatrout still exhibited a significant selection for shrimp (77 and 78% of the prey eaten were shrimp). Variability among sectors and between replicates of these feeding trials was low (Table 1), which indicated that there was little variability in prey selection among the individual predators and that experience gained during a feeding trial did not affect the results of subsequent feeding trials. A comparison of pooled data from the feeding trials without an accessible substrate and those with a sand substrate showed that the number of each prey species eaten

TABLE 1

Selection by spotted seatrout (160–210 mm TL) for brown shrimp and spot (59–85 mm TL) in 24-hr feeding trials without an accessible substrate for burrowing (without substrate) and with a sand substrate. P = probability that the percentage of shrimp eaten of the total number of prey eaten equals the expected 50% (chi-square analysis).

Feeding Trial	Number of Predators	Number of Prey Present: Shrimp	Spot	Number of Prey Eaten: Total	% Shrimp	P
Without Substrate I	4	40	40	19	100	<0.005
Without Substrate II						
Sector 1	2	20	20	9	100	
Sector 2	2	20	20	8	100	
Sector 3	2	20	20	8	100	
Total	6	60	60	25	100	<0.005
Sand Substrate I						
Sector 1	2	20	20	8	75	
Sector 2	2	20	20	6	83	
Sector 3	2	20	20	8	75	
Total	6	60	60	22	77	<0.01
Sand Substrate II						
Sector 1	2	20	20	10	80	
Sector 2	2	20	20	8	75	
Sector 3	2	20	20	9	78	
Total	6	60	60	27	78	<0.005

was dependent upon substrate accessibility ($P < 0.005$, G-test of independence, Sokal and Rohlf 1981). At the initiation of the feeding trials (1200 hr) with sand substrates, 62 and 67% of the shrimp were burrowed (over one-half of the body beneath the substrate surface), and burrowing apparently decreased the availability of brown shrimp to predators.

The control data indicated little interaction between the two prey species. Mortality unrelated to predation was low. Only one of 100 shrimp and four of 100 spot were not recovered alive from the controls over the four feeding trials.

In holding tanks, spotted seatrout also selected brown shrimp over spot as prey. In these tanks, shrimp did not burrow, and only one individual of each prey species was available to the predator. Shrimp were eaten first 81% of the time (21 out of 26 observations), and this percentage was significantly different from the expected 50% (chi-square test, $P < 0.005$).

The feeding behavior of spotted seatrout in the laboratory was similar to the behavior described by Lascara (1981) for weakfish (*Cynoscion regalis*). The seatrout usually approached the prey slowly up to a distance of approximately 10 to 30 cm. If the prey did not swim away during this approach, a rapid strike by the trout generally resulted in prey capture.

Selection between the two prey species in the small holding enclosures did not appear to be related to prey detection since both prey species were approached frequently. The approach of a predator, however, elicited an escape response in spot more frequently than in shrimp. In the larger concrete tank, prey detection was undoubtedly an important factor, especially in the presence of a sand substrate.

When juvenile spot and pinfish were offered as prey, the spotted seatrout fed upon spot first 89% of the time (16 out of 18 observations). This percentage was significantly different from the expected 50% (chi-square test, $P < 0.005$). The relatively short duration of exposure to pinfish as prey (only 6 days versus several months for spot) could have affected these results. Observations on feeding, however, indicated that seatrout often attempted to eat pinfish, but pinfish excaped predatory attacks more frequently than spot.

Shrimp and spot sizes (total length) were similar in all four feeding trials conducted in the concrete tank. Although the seatrout ate shrimp of all sizes, they preferentially preyed upon the small shrimp. Approximately one-half of the initially available shrimp were ≤ 73 mm (Fig. 1), but more than 73% of

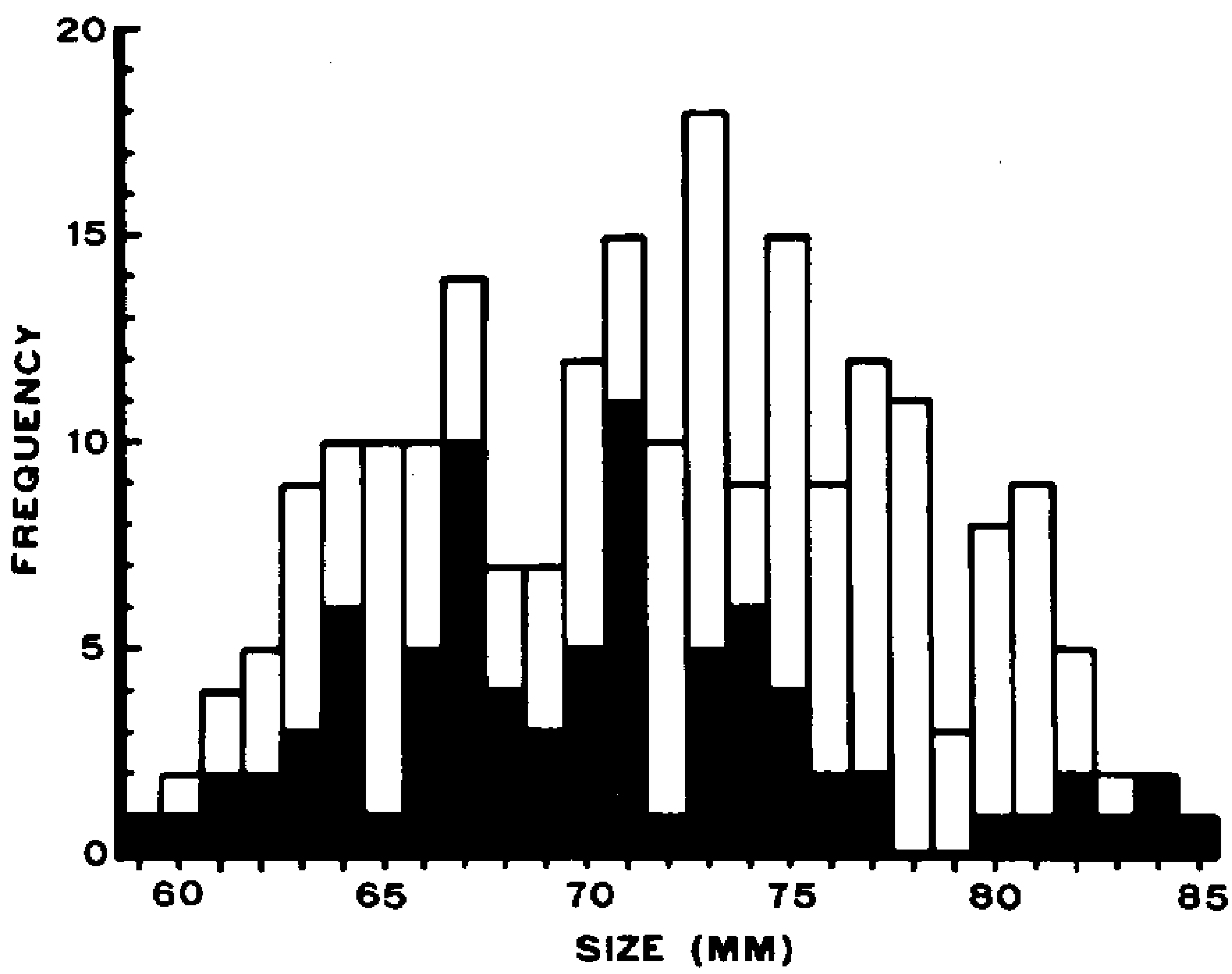

Fig. 1. Size-frequency distributions of brown shrimp eaten (solid bar) and not eaten (open bar) by spotted seatrout (160–210 mm TL) in four selective predation feeding trials. The total height of the bar represents the frequency of each size initially available.

the shrimp eaten were from this half of the size-frequency distribution. The difference between the size-frequency distributions of eaten and not eaten shrimp was highly significant ($P < 0.001$, Kolmogorov-Smirnov two-sample nonparametric test, Sokal and Rohlf 1981). The small number of spot eaten in the prey selection feeding trials prevented a valid statistical analysis of size selection. In the feeding trials with a sand substrate, however, the 11 spot eaten out of the 120 available were mostly from the lower half of the size-frequency distribution. Seatrout feeding only on spot also selected small prey (P = 0.006, Kolmogorov-Smironov test), although the spot available (68–92 mm TL) were slightly larger than in the prey selection feeding trials (Fig. 2).

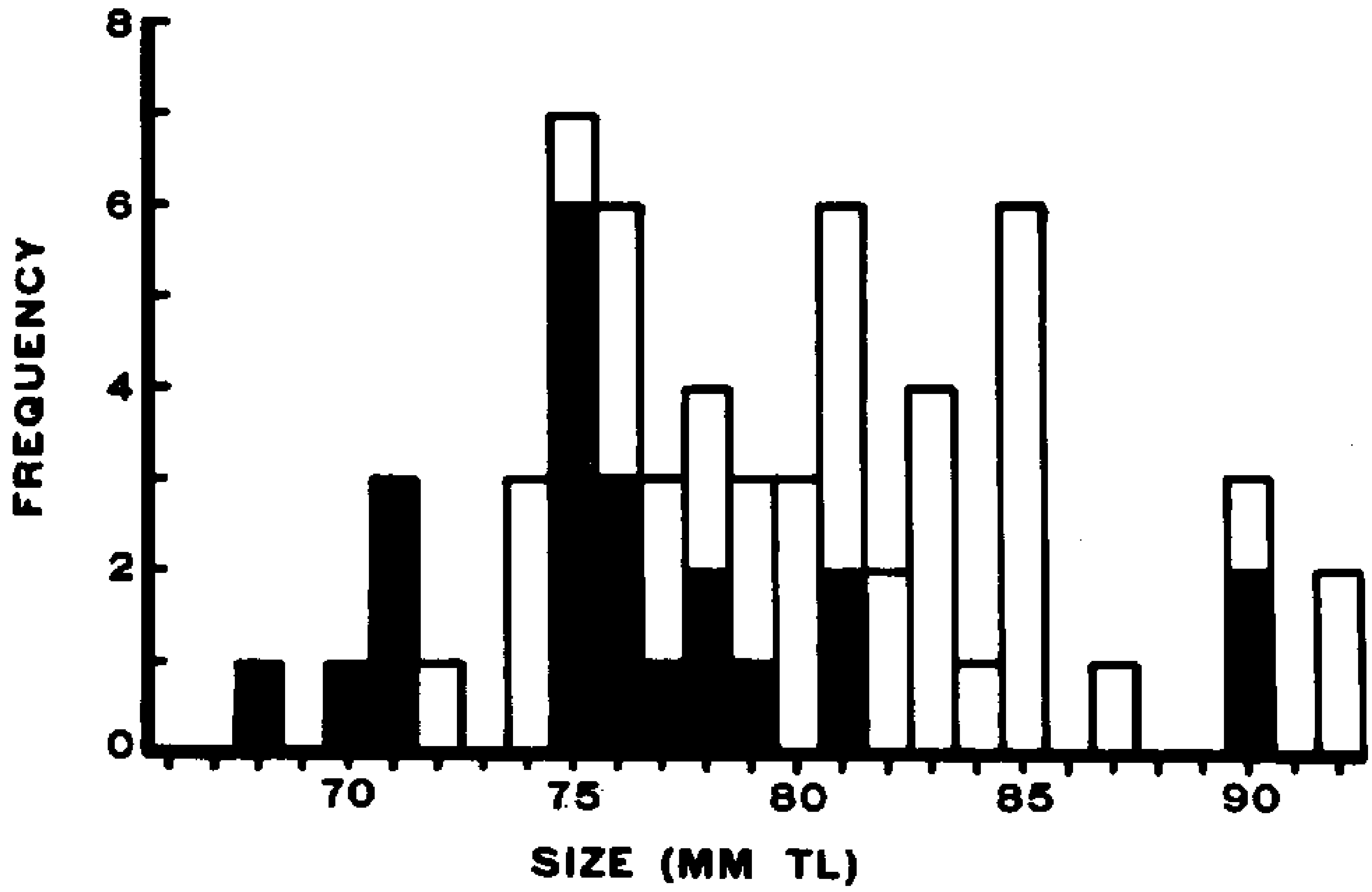

FIG. 2. Size-frequency distributions of spot eaten (solid bar) and not eaten (open bar) by spotted sea trout (170–212 mm TL). Only spot were available as prey, and the total height of the bar represents the frequency of each size initially present.

DISCUSSION

Our laboratory data indicate that spotted seatrout select for brown shrimp over juvenile spot, and for juvenile spot over juvenile pinfish. Both spot (Pearson 1928, Diener *et al.* 1974, Mahood 1974, Danker 1979) and pinfish (Gunter 1945, Moody 1950, Seagle 1969) are natural prey of spotted seatrout, and our results suggest that seatrout select juvenile brown shrimp over juvenile fish as prey.

Behavioral characteristics of prey can reduce their availability to predators, and the presence of prey species in equal numbers does not assure equal availability. Although spotted seatrout fed exclusively on brown shrimp as opposed to spot in experimental tanks without an accessible substrate, burrowing by shrimp in tanks with a sand substrate apparently reduced the availability of brown shrimp and increased predation on spot. Schooling behavior of fish has also been shown to reduce the success of predatory attacks (Neill and Cullen 1974), and schooling by spot may have contributed to our results. In the experimental tanks without an accessible substrate, 20–40 spot were present per sector, and schooling was common.

No spot were eaten in these feeding trials. In holding tanks, prey species were offered in pairs which prevented schooling, and spot were eaten first in 19% of the observations. No burrowing by shrimp occurred in any of these feeding trials. The inability to school may have increased predation on spot in the holding enclosures.

Availability of prey to predators is also dependent upon prey size, which can affect both prey detectability and catchability. A large amount of literature has documented the importance of size-selective predation by fishes in freshwater systems (see Zaret 1980 for review) and estuaries (Parker 1971, Vince, Valiela, Backus, and Teal 1976, Van Dolah 1978, Nelson 1979). Although a narrow range of prey sizes was present in our feeding trials, the spotted seatrout exhibited a significant selection for small prey. This indicates that relatively detailed analyses of the size-frequency composition of potential prey are necessary in field studies, and that the selection of prey species, as determined from stomach content analyses of field-collected spotted seatrout, may in part be related to size-selective predation. Selection by seatrout for small shrimp also has potentially important ecological implications. If predators with the most impact on shrimp mortality, select for small shrimp, shrimp may find refuge from predation in size. Rapid growth rates (0.7–3.3 mm/day) exhibited by juvenile brown shrimp (see Knudsen, Herke, and Mackler 1977 for review) may be an evolutionary response to size-selective predation. A similar hypothesis has been proposed by Parker (1971) for juvenile salmon.

Our study on spotted seatrout confirms the importance of prey availability in selective feeding. The data suggest that under conditions of equal availability, seatrout strongly select brown shrimp over juvenile fish. Behavioral responses of prey to habitat characteristics can alter availability to predators. Burrowing effectively reduces the availability of shrimp, and subsequently their susceptibility to predation. Responses to other habitat characteristics such as vegetation (Zimmerman, Minello and Zamora in press) may function in a similar manner to reduce shrimp availability to fish predators.

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